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ABSTRACT

Modern decision-makers using the systematic approach known as systems analysis as a decision-making tool are faced with the delicate problem of choosing the correct method of analysis and application of resources to this analysis effort. This study examines the broad concept of systems analysis. The application of two methods of analysis, cost-effectiveness and the pay off table, is illustrated. It concludes that an understanding of the factors a decision-maker must consider in selecting the method and extent of analysis effort is necessary in order to perform fruitful analysis efforts.

PREFACE

This study investigates the overall diagnosis required of military and civilian managers when selecting the method and extent of analysis effort required to accomplish their basic objectives. The writer believes that contrary to popular belief, systems analysis requires careful examination of basic objectives and efficient application of all resources to achieve desired objectives.

The writer chose this area primarily as a result of the challenge issued by Lt General John W. Carpenter III, Commander, Air University, in an address to the students of Air Command and Staff College in September 1965. In his address General Carpenter forcefully emphasized the general inadequacy of Air Force officers in the field of systems analysis. Moreover, General Carpenter stressed that Air Force officers must become more familiar and active in this field in order to present the Air Force position more accurately. He further emphasized the need for competent military to gain acceptance by the strong analytical element within the Defense Department.

The basic objective of this paper will be satisfied if, even in a small way, it improves the military manager's understanding and ability to apply efficiently his resources to systems analysis and his decision-making needs.

The writer would like to express his sincere appreciation for the efforts devoted by Lt Col Lawrence R. Pote and Lt Col John J. Boyne toward the completion of this thesis. The guidance provided by these officers and the patience and assistance of my dear wife were instrumental in the successful completion of this project and I am deeply grateful.

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INTRODUCTION

The problems of military choice in the fifties were (or were thought to be) simpler than those with which we shall deal in the future. In the past, little use was made of any systematic method in decision-making. Acceptable results using rationalizing choice were relatively easy to come by--once ever-present bureaucratic obstacles were overcome.[1] Decisions based totally on rationalization and intuitive judgment are no longer acceptable. Modern decision-makers must avoid the temptation of single judgment and use the systematic methods of analysis now available to them.

The function of the new analytical technique commonly referred to as system analysis has been to provide decision-makers with a systematic method by which they may determine relevant alternatives or choices in solving problems. This methodology does not provide the most correct choice in any sequence or priority, but rather it attempts to eliminate the undesirable courses of action and wasteful choices. In using this methodology the decision-maker must recognize the essential characteristics and not exaggerate its usefulness . . . actual or potential.[2]

Rising costs, sophistication of systems, and increasing uncertainties does not allow high level decision-makers the luxury of gross errors of judgment, especially in the area of treating uncertainty. The use of system analysis provides a method for treating uncertainty and at the same time providing the decision with efficient alternatives.

> The elimination of gross inefficiencies permits us to specify more precisely major uncertainties. This is important in that in some ways these uncertainties are increasing rather than receding, particularly those relating to objectives or measures of effectiveness.[3]

An illustration of this type of uncertainty would be the inability of the Department of Defense in peacetime to measure the performance of many of our defense systems against our enemy's offensive threat.

The crucial choices facing decision-makers, military and civilian at all levels, warrants a comprehensive understanding of all the possible methods of analysis available to them to aid in making proper choices. Similarly, the decision-maker must choose his method of analysis based on his judgment as to how much of his resources he should expend on the analysis effort.

Prior to embarking on any analysis effort a critical diagnosis is necessary. "Accurate diagnosis is the essential first phase of sound decision-making. Unless the initial diagnosis is correct, all subsequent planning will be futile."[4] The amazing success of American industry during the last half-century with scientific management has led most modern managers to regard intuition as a last resort.[5] Mr. Alfred P. Sloan, Jr., in commenting on the phenomenal success of General Motors Corporation, which he headed for so many years, said, "Few people are willing to go to the length we do to get all the facts possible and look at a problem from all angles before making a decision."[6]

Many times, as in the case of defense systems, we are confronted with a situation that is complex, principally because so many different things need improvement. Undoubtedly, some connections exist between problems that are very similar and we will sometimes yield to one if, by doing so, we can improve performance with respect to the others. At what point do we stop trading? If we are uncertain about the answer, it must mean that performance is in a range in which we do not feel strongly about minor differences. This is another way of saying that this problem or aspect of a larger encompassing one is no longer important.[8] This is what the writer contends is a critical point in the diagnosis period for a manager. This is the point where he will make a decision as to how much, if any, of his resources he should expend in analyzing this problem.

Statement of Problem

This thesis will examine some of the factors that decision-makers must consider in making a decision on the type and extent of analysis to be performed.

Objectives

The main objective of this thesis is to provide an insight into a systematic methodology for selecting the method of analysis applicable to a given situation and for determining how much analysis resources should be expended.

The specific objectives are:

1. To examine the basic history and theory of system analysis.

2. To examine two types of system analysis with an example of each.

3. To examine the application and problems associated with systems analysis.

4. To examine specific factors decision-makers must consider in choosing the method and extent. Provide through application one method for selection of type and extent of analysis.

Limitations and Assumptions

This study does not consider complicated or sophisticated mathematic examples or specific mathematical areas of analysis. It will deal with the general problem faced by a manager assuming the detailed data would normally be prepared by analysts.

It is assumed that decision-makers will expend their resources only after careful examination of the problem and careful choice of analysis has been made. If decision-makers fail to examine all necessary factors involved with selecting their method and expenditure of resources, this thesis will provide little service. Finally, it is assumed that decision-makers will always have some constraints in the form of scarce resources which will necessitate a critical diagnosis of their problem and the manner and depth of analysis needed to produce relevant alternatives.

Overview

Chapter One presented the problem and objective of this thesis.

Chapter Two will describe the theory of system analysis, the need for system analysis, and some limitations to system analysis.

Chapter Three will present two types of system analysis--cost-effectiveness analysis and payoff tables.

Chapter Four will demonstrate application and problems associated with system analysis.

Chapter Five will show a method that a decision-maker can use in choosing the method and extent of analysis effort.

CHAPTER II

SYSTEM ANALYSIS

Our modern world and particularly the United States finds itself at a dangerous crossroads in the race for technological supremacy. If we fail to take the right path to technological supremacy, it can be disastrous to our way of life; but success will provide the world and our nation the security and progress we so desperately seek. Rising uncertainties and ever increasing sophistication in the state of the art has provided this crossroad—a crossroad of choice. No longer can modern military decision-makers rely on intuitive judgments alone. The experiences of the past no longer lend themselves to the complexities and uncertainties associated with the problem of choice in the present age. In response to this problem of choice, a systematic method of approaching problems and selecting from among alternatives has evolved. This methodology using both data acquired from scientific methods and intuitive reasoning is called system analysis.

The use of systems analysis in decision-making requires the expenditure of varying amounts of the users resources. The purpose of this chapter is to provide useful, general information on system analysis and to examine the systematic methodology used in successful analysis efforts. Careful consideration of the concepts presented in this chapter will provide a better framework for those contemplating use of system analysis and enable them to expend their resources in these efforts more efficiently.

What It Is

System analysis is still largely an art and not a science.[1] It is a way of thinking--an approach to the modern problems of choice. System analysis is not a true scientific approach because all of its predictions and alternatives cannot be verified. E. S. Quade says that:

> The phrase "systems analysis" refers to formal inquiries intended to advise a decision-maker on the policy choices involved in such matters as weapon development force posture design, or the determination of strategic objectives.[2]

A form of systems analysis was first used during World War II when it became apparent to military men that many of the systems being developed involved technical know-how which was foreign to past military experience or training.[3] Radar was a good example of a new concept that could not be exploited by military planners alone. To meet this challenge a "scientific" approach was instituted combining the talents of many professions such as physicists, mathematicians, and similar highly specialized areas. Initially, this early form of analysis was called "operations research." Through time the term has evolved to the term "systems analysis." The change from "operations research" to "systems analysis" has resulted primarily from the postwar military studies which were mainly concerned with broad, complex problems and weapon systems. The use of the analysis process in evaluating and choosing among systems quite naturally came to be known as "systems analysis."[4]

Today, the major difference between operations research and systems analysis lies in emphasis. While both deal with mathematical models and economic optimization techniques, "systems analysis deals with conceptual problems."[5] Those where "the problem lies in deciding what ought to be done . . . not simply how to do it."[6] Here lies the point of emphasis between operations research and system analysis. With operations research the emphasis is on how to get the most out of what we have, the maximization of efficiency in systems or equipment already developed. On the other hand, when dealing with systems analysis we tend to think in terms of "high level," "broad," "long-range," "choice-of-objectives" which normally are associated with sophisticated, present and future needs. Due to its nature systems analysis is normally associated with national objectives. While the consideration of optimization, that of maximizing achievement of objectives and minimizing cost, is present, it is only a stage of the overall system analysis.

> In short, the analysis of weapons or strategies for future wars presents a new kind of problem, essentially different from any treated by operations research in World War II, or even the Korean War. The conditions of research are different. There is usually more time; there are large computational facilities; there is a great deal of peacetime data available, but virtually none of the desired operational information.[7]

One of the strong points of system analysis lies in the systematic methodology used. The process is an iterative one, a cycle starting with problem formulation, search, model building, and interpretation. It is a discipline of weighing results, questioning assumptions, investigating new alternatives, and reformulation in order to obtain the spectrum of alternatives believed to be sufficient to produce all relevant alternatives. The analyst initially enters the cycle with his problem and this is called the formulation stage. He then moves to the search stage, then to the exploration stage, and finally to the interpretation stage. When discussing the cyclical movement of the analysis activities, it is important to note that the analyst, through the use of a systematic approach, has the option to stop at any point and retrace or alter any input to the analysis effort. The analyst may complete the cycle and get results that don't agree with his intuitive judgment. Some of the initial data may or may not be verified. This is the nature of the method, in that much of the work done in systems analysis deals with future requirements and uncertainty. It is this complementing action of using data from both intuitive reasoning and scientific methods that eventually improves the validity of the resulting choice of alternatives. Thus we can say that systems analysis is a logical and continuing process.

> It is a cycle of definition of objectives, design or alternative systems to achieve those objectives, evaluation of the alternatives in terms of their effectiveness and costs, a questioning of the objectives and a questioning of the other assumptions underlying the analysis, the opening of new alternatives, the establishment of new objectives.[8]

When dealing with broad national objectives, the analyst often finds it difficult to start his analysis efforts. The first phase, that of problem formulation and defining objectives, can be extremely difficult due to vague or non-existent statements of national objectives. This initial phase may be shrouded under a blanket of secrecy that can only allow for intermediate objectives and criteria that approximate what the analyst judges to be the higher level of objectives.[9] While working in the formulation stage, the analyst can often uncover objectives that were overlooked or eliminate some that were previously accepted. It is very important that correct objectives be established. The wrong initial choice of objectives means that the analyst may not be working on the correct problem.[10] The problem of using incorrect objectives can stem from another source; that of using persons of such wide variation in professional background as to cause misinterpretation of problem and objectives. It appears most important, then, that all involved have a concrete hypothesis from which to work. The idea is to make clear the objectives and structure of the analysis to all engaged in the analysis effort.[11]

The second phase of the analysis cycle is the search phase. It is here that the analysts are probing facts on which to base the analysis. It is important to recognize that the analyst must handle the facts and quantitative data honestly--with no bias and insure that alternatives are not arbitrarily suppressed.[12] Value judgments must enter into the analysis effort, but it is expected that the analyst will identify these judgments to the decision-maker. The area of cost is naturally considered, but only as a part of the study of resources versus objectives.

The third stage of analysis is the exploration stage. It is here that many analyses fail due to improper model construction. At this stage, models are constructed and mathematical computations, comparisons, and cost-effectiveness applied to the models. In systems analysis it is important to remember that the mathematician must deal with the real world. It is not uncommon for mathematicians to become slanted toward the computation of the analysis model and move away from the original questions of the study.[13]

The last stage of the normal analysis is the interpretation stage. It is here that all the non-quantifiable data, uncertainties, and contingencies are considered in relation to the solution derived from the model. At this point conclusions are drawn. It is possible that the final results are not satisfactory to the analyst and he goes back and reworks through all or part of the process. When he presents the conclusions to the decision-maker, he must also present what he thinks the solution implies. It must be remembered that the model is only an indicator, not a judge.[14]

The analyst at this point is not making decisions, rather he is helping the decision-maker make the proper choices.[15] He is assisting decision-makers in the expenditure of their nation's or company's vital resources based on considered judgment of what the analysis indicates to be the most correct choice of alternatives.

Decision-making in its simplest form can be defined as the selection of an alternative or alternatives from one or several possible alternatives. It is a method for determining the ultimate course of action. System analysis is much the same, but there is a significant difference. In system analysis the scope is usually of a broad nature and the discipline is systematic. The complexity of multiple objectives, uncertainty, and constraints in the form of resources, requires a methodology that treats the whole system. Its purpose is to formulate and reformulate every element to insure that the resulting alternatives represent the best possible choices to the decision-maker as he goes about the task of deciding between these choices and expending his resources.

The Need for Systems Analysis

The Defense Department today is the largest single business in America. It is the heart of a complex, interdependent team, widely diversified yet mutually oriented. This Department is responsible for spending nearly 10 per cent of the national income of this country. It employs 3.7 million people directly in and out of uniform and millions more indirectly in every aspect of our economic life.[16]

Control of the complex Defense organization and efficient direction of its power and resources toward achievement of its mission of national security requires more than intuitive and parochial judgments. It requires systematic approach at all levels. The method for gathering, analyzing, and presenting the data necessary for decision-making has, due largely to the extensive and imaginative use of automatic data computing by the military, advanced to a point where centralized decision-making is both efficient and effective.[17] This unity and commonality of systems eliminates some of the major deficiencies of past decades when dealing with national security. The past systems were prone to independent procurement policies, interservice rivalries, and great redundancies in some types of capabilities and serious shortages in others.

According to Alain Enthoven, Deputy Assistant Secretary of Defense for Systems Analysis, during the Eisenhower era there was almost complete separation between planning and decision-making on systems and forces on one hand, and budgeting on the other. The services made decisions on national security based on their estimates. Costs were not introduced systematically to test the feasibility of either the program or the allocation. The full-time or phased costs of the proposed forces were not presented to the Secretary of Defense. Because, in many instances, the costs were small in the early years, many programs were started that could not be completed under existing budgets.[18] Systems analysis did not resolve this problem but Secretary of Defense McNamara, using systems analysis as a tool, did. Mr. James R. Schlesinger puts it this way:

> The function of the new analytical techniques has not been to give us the correct choice in making military decision, but rather to eliminate some very bad and wasteful choices. In our enthusiasm regarding analysis, we should not exaggerate its accomplishments actual or potential.[19]

Limitations to Systems Analysis

At the present time systems analysis is possibly the best managerial tool available, but the future may find it inadequate. As the domain of systematic quantitative analysis increases, and as the irrational waste recedes, our attention will turn to those aspects of national security in which quantitative analysis cannot provide choices: the problems of objectives, uncertainties, and strategic choice.[20]

One of the major limitations in using systems analysis continues to be in the area of treating uncertainty. There are several kinds of uncertainty: the uncertainty in planning factors; the enemy and his reactions; the strategic context such as "Who will be our enemies, or who will be our allies?," "Will there be a war during the period covered by our analysis?;" technological uncertainty; and lastly, statistical uncertainty.[21] If we look only at the statistical uncertainty, we find that it is obvious that using cost data in a cost-effectiveness analysis of a weapon system is feasible but how do we measure the effectiveness from a military standpoint? Dr. E. S. Quade infers that there is a way to measure military effectiveness:

> Having agreed upon the objectives and determined a way to measure the military effectiveness of the system, the analysis becomes a cost/effectiveness analysis.[22]

The writer feels that there is one major premise of systems analysis that is most often overlooked. That premise is that analysis is still an art rather than a science. It is done in some cases using data thought to be right and possible, but with data no one can verify and that can't be justified. The user must accept as inputs many relatively intangible factors which are derived from human judgment and present answers which are then used as material for other judgments. This judgment is supplemented by inductive and numerical reasoning, where possible, <u>but it is judgment none-the-less</u>.[23]

In summary, "the systems analyst is not restricted to the systems he starts to compare. The most valuable function of systems analysis is often the stimulus it gives to the innovation of better systems."[24] Systems analysis is necessary in modern national security decision-making. It is fair to say that those who are most critical of its use in solving the complex problem of national security have not as yet provided any alternative method.

CHAPTER III

METHODS OF ANALYSIS

In the preceding chapter, the term "system analysis" was defined in its broadest sense relative to the decision-making process. The writer will now examine in more specific detail two of a number of precise methods of analysis that a decision-maker may choose between. While systems analysis is normally associated with the Department of Defense, American industry is adapting this methodology on an increasing scale. The two types of analysis presented in this chapter are representative of analysis efforts employed by the Department of Defense and Industry. The key to success in decision-making does not of necessity lie only in the analysis itself, but rather the decision-maker must assure that the proper type of analysis has been selected and available resources are efficiently expended. Analysis like economics involves the allocation of scarce resources.

> Resource limitations are our starting point because in all problems of choice we strive to get the most out of what we have. To put it another way, we try to use the resources that are available to us so as to maximize

> what economists call "utility." Resources are always limited in comparison with our wants, always constraining our action.[1]

It is this modern theory of utility, or marginal analysis, and more specifically "cost-effectiveness" that will be treated first.

Cost-Effectiveness Analysis

Once the decision-maker has assured himself that his problem is quantifiable--that is, having the capability to measure both the cost and the effectiveness--he then proceeds to examine it, to establish his objectives and his criterion. It is at this point that common sense tells the decision-maker that without some constraints on the level of effectiveness or total cost, the ratio may develop extreme points of effectiveness or cost. It becomes apparent that it is foolhardy for the decision-maker to work at either extreme, for as in the case of defense spending, a decision based on cost alone might prove to be an inexpensive way to invite and lose a war.[3] As Mr. Hitch stated: "Resources are always limited in comparison to our wants, always constraining our actions."[4]

The writer accepts this condition and promulgates the position that with budget limitations, as in the case of defense spending and the demands of national security, the use of cost-effectiveness analysis is a valuable decision-making tool. Having established the fact that the rational decision-maker will normally avoid the extremes of cost versus effectiveness, we shall now look at two examples of how this type of analysis can assist in determining the best choice of alternatives. It should be pointed out that these are over-simplified examples intended only to demonstrate the technique involved.[5]

Type I. The problem is to maximize the number of targets destroyed with a given budget of XX dollars. The alternatives for accomplishing this task may be:

1. Use all type B (bomber).
2. Use all type M (missile).
3. Use a combination of type B and type M.[6]

Figure 1 depicts how many bombers and missiles that can be bought with XX dollars (it assumes that the cost of each is the same). The range of choice is from all-bomber force of 150 B's to all-missile force of 300 M's. The "exchange curve" (straight line A-B) gives the comparison line for the various combinations of bombers or missiles that can be purchased with the fixed budget of XX dollars. The problem is now to determine the optimal mix of bombers and missiles in order to maximize the targets destroyed.[7]

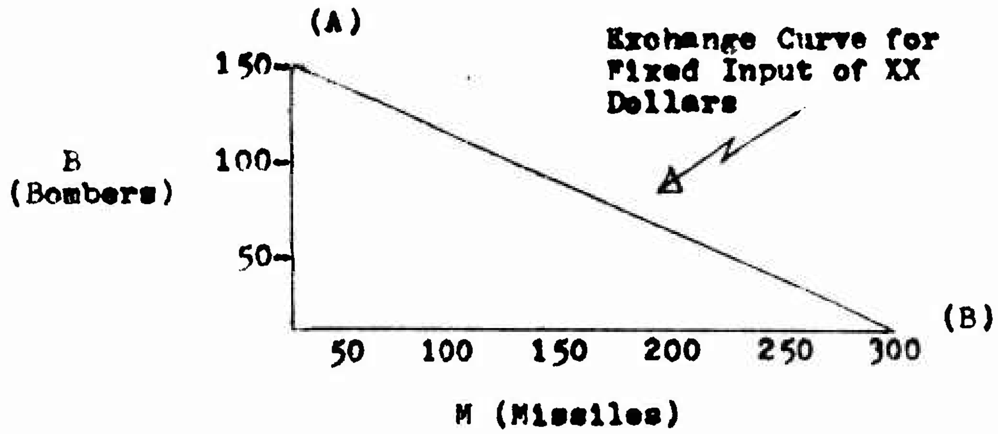

FIGURE 1*

Figure 2 depicts an assumption of the target isoquants possible and the various combinations of bombers and missiles and their target kill potential. The method of determining how these isoquants curves are actually derived is quite complicated and beyond the scope of this thesis. An appreciation of how these curves are used in cost/effectiveness studies is not conditioned upon an understanding of how they are constructed.

In Figure 2 the point within the small circle (Point P) represents the optimal mix of 85 bombers and 130 missiles to destroy 200 targets. No further

*This model obtained from "The Cost Effectiveness Method," Research Study, Air University, 1964.

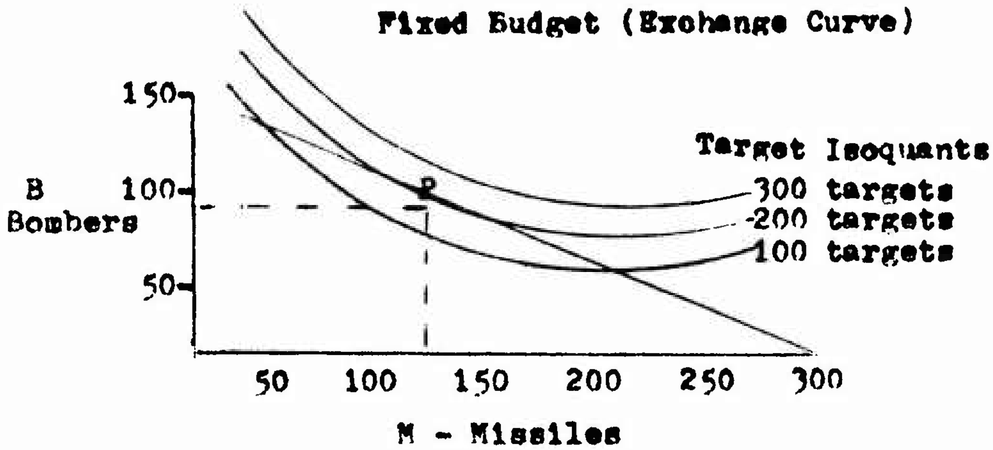

FIGURE 2*

substitution of B for M or M for B would increase the total possible number of targets that could be destroyed.[8] In short, on the basis of a fixed budget, this point "P" gives the best mix of bombers and missiles with which the maximum number of targets would be destroyed. Having seen the application of economics to maximize the target kill with a fixed budget, we will now turn to the problem of minimizing cost with a fixed or specified level of effectiveness.

Type II. This problem differs from Type I in that we are given a fixed level of target kills required and we are to minimize the cost. Once more the model will be simplified to insure complete understanding of the

*This model obtained from "The Cost Effectiveness Method" Research Study, Air University, 1964.

technique. As in Type I, we find three alternatives:

1. Use all bombers.

2. Use all missiles.

3. Use a mix of bombers and missiles.

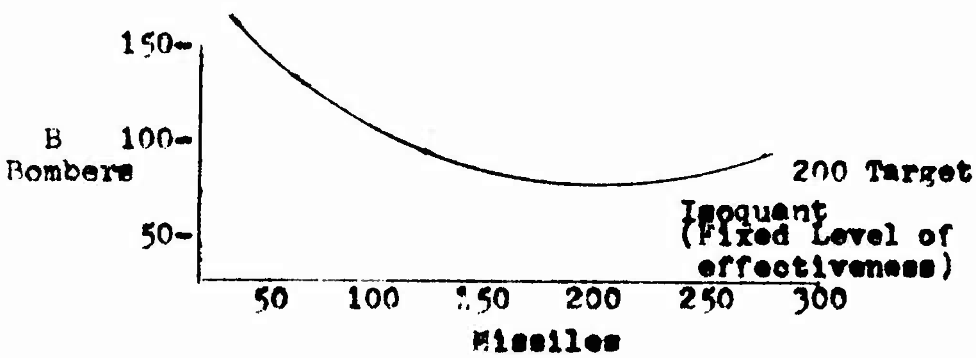

FIGURE 3*

In this problem we have a fixed level of effectiveness of 200 targets. We must determine at what point on the target isoquant we minimize the cost by plotting the alternatives shown above.

We find that the exchange curve which is tangent to the target isoquant at Point P is the same as Point P in Type I, that is the same mix of bombers and missiles both most efficient and minimal cost wise.[9]

*Model obtained from "The Cost Effectiveness Method," Research Study, Air University, 1964.

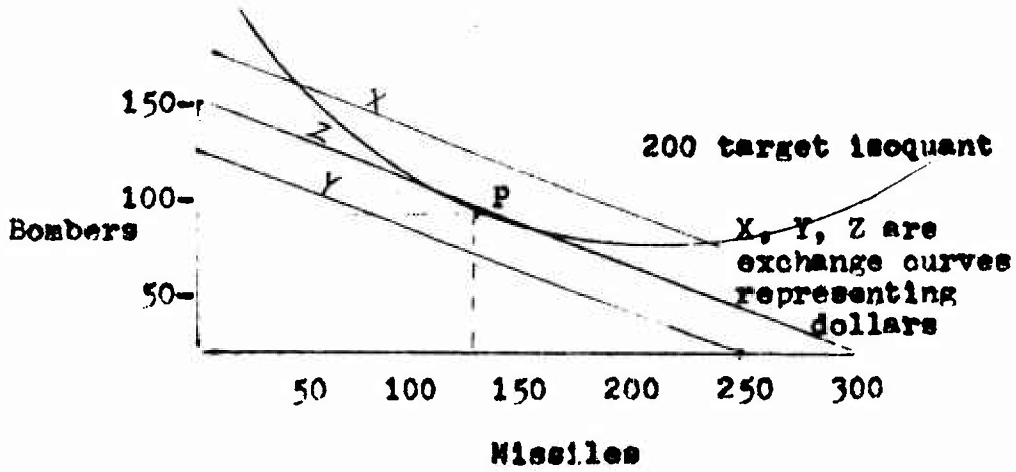

FIGURE 4*

It is important to note that the budget line and the target assigned are provided the analyst as a result of separate or post analysis. Recognize that the X, Y, Z would not be truly straight lines, but would be curved because of the varying costs of large versus small production runs of either bombers or missiles. For purposes of simplifying the illustration, they are shown as straight lines.

The writer has attempted to show the very basic formulation of cost/effectiveness through the use of economic models (Figures 1-4). The proper use of data derived from such a model will be very helpful to the analyst and ultimately the decision-maker, but there

*Model obtained from "The Cost Effectiveness Method," Research Study, Air University, 1964.

are some considerations that must be remembered:

1. While cost estimates are basically easy to determine, the estimate on levels of effectiveness are often only educated guesses.

2. The factor of uncertainty and changing technology.

3. Incompleteness—both as result of the limitations of time and money with effect on the depth of the inquiry and the exactness of data inputs.[10]

In the case of federal expenditure for defense, the use of cost/effectiveness analysis is a systematic rational way of looking at a problem and gives at least a smaller margin of error than the previous practice of "trade off and bargaining between the service for funds." The following is an appraisal of the value of this type analysis by Robert S. McNamara:

> In adding to a defense budget as large as the one we now have, we begin to encounter the law of diminishing returns, where each additional increment of resources applied produces a smaller increment of overall defense capability. While the benefits to be gained from each additional increment cannot be measured with precision, careful cost/effectiveness analysis can greatly assist in eliminating these program proposals which clearly contribute little military wealth in relation to the resource expenditures involved. We have applied this principle throughout our program and budget reviews.[11]

The decision made by the Department of Defense can not be considered rational if adequate knowledge of alternatives in terms of their military worth are not related to their cost.[12] We cannot be so poor as to fail to pay the necessary price for national security nor rich enough to squander our resources in the name of national security.[13] The value of cost/effectiveness analysis and its economic background cannot guide us to a total solution, except in a very formal and empty sense. However, it can be a useful guide in examining alternatives and making improvements. We shall now examine another decision-making tool that is found more in the business world than the government.

Pay Off Tables*

A method of analysis which is less complicated than cost/effectiveness analysis but nevertheless very helpful in decision-making is use of the "Pay Off Table." This method of analysis has been developed with certain human limitations in mind. The first limitation is that the human mind does not function well when dealing with multi-dimensions, with handling two sides of a question simultaneously. The second limitation is that

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*The thoughts and models on the subject of Pay Off Tables were obtained from a lecture by Dr. Paul A. Vatter, "Decision-Making," to the students of Air Command and Staff College 14 September 1964.

frequently "seat of the pants," intuitive judgment will not select the best choice of alternatives. The very heart of any systematic analysis is the adequate search for and examination of all possible alternatives and the proper treatment of uncertainty. What often separates the good from the poor decision-maker is lack of imagination of creativity and improper treatment of probability and uncertainty.

The method used by Julius Caesar to devastate his foes was to divide his foes into segments and conquer them individually, then regroup his forces. The principle of dividing and conquering--the breaking down of complex problems into segments and applying judgment and experience--is the foundation of the "Pay Off Table."

To describe the pay off table and its possible use by decision-makers the writer will present an over-simplified situation and model. It should be noted that the points are over-simplified purely for ease in understanding by the reader and does not constitute any inherent weakness in the method. The reader should assume that he is acting in the role of a company which produces an accepted type of consumer goods. The research division of the company has proposed a new product to complement its existing product line. As head of the company you feel the product has possibilities and decide to make a decision on whether to place it on the market or pass it by. Based on the depth of study required and available data and other resources, it is decided to use the "Pay Off Table" method to analyze the situation.

In dealing with the "pay off table" there are three major aspects of consideration:

1. The monetary aspect--an analysis of the expense involved and the expected revenue.

2. The aspect of forecasting--the demand, the uncertainty.

3. The risk aspect--how much is to be gained or lost if placed on the market? What premium would the company want to make in order to take a risk? If at this point an informal decision was made on snap judgment, the melding together of all three dimensions of this problem could result in disaster.

The company engineers state that there are two processes for production of the new product:

Process A

1. The product will be made on a simple machine that the company leases for $1,000 per year.

2. The variable cost per unit of production will be $1.00.

Process B

1. The product will be made using a highly automated complex piece of machinery which the company will lease for $5,000 per year.

2. The variable cost per unit of production will be $.50.

For the purpose of this model, assume the traditional market price of this type product to be fixed at $1.50 per unit. The model (Figure 5) is an over-simplified example of the technique used in this type analysis. The first column, for example, shows only three volumes of sales. This range could be varied from zero to points in-between those given or above the highest shown. The alternatives for the company have been limited to three; again, others could be considered.

PAY OFF TABLE

	Alternatives		
Sales Volume	Don't Produce	"A" Method	"B" Method
10,000	0	+4,000	+5,000
5,000	0	+1,500	0
1,000	0	-500	-4,000

FIGURE 5

As stated previously, this method of analysis depends on breaking down the problem and solving each aspect separately.

Taking the first aspect, "the monetary aspect," we construct the table (Figure 5). In entering information to the table, the first alternative of not producing the item would have us place zeros by all sales volumes as we didn't make any money and we didn't lose any. Looking at alternative "A" with a fixed cost of $1,000 per year and variable cost of $1 per unit, we find that 1,000 sales at $1.50 per sale we would lose $500 ($2,000 cost-$1,500 sales revenue). Using the same cost data with 5,000 sales, we will show a profit of $1,500 ($7,500 sales-$6,000 cost). And finally, using the same cost data with 10,000 sales, we would make a profit of $4,000 ($15,000 sales-$11,000 cost).

Moving to the last alternative, "B," with a fixed cost of $5,000 per year and variable cost of $.50 per unit, we again enter the table with 1,000 sales at $1.50 per sale. At 1,000 sales we enter a loss of $4,000 $5,500 cost-$1,500 sales); with 5,000 sales we enter zero or break even ($7,500 cost, $7,500 sales); and at 10,000 sales we show a profit of $5,000 ($75,000 sales, $10,000 cost). Thus we have handled separately the "monetary" aspect without complicating our mental process with consideration of the next aspect--that of "forecasting."

In the area of "forecasting," the first consideration must be the critical event--the demand. What is going to be the demand for this product? We are now dealing with an uncertainty. The questions of product appeal, product quality background data, and finally, just how strong do we think the market will be, must be equally considered. It is at this point that we work with betting odds. We will say that the odds are one in two that we will sell 1,000 and one in three that sales will be 5,000, and one in six that they will be 10,000. These odds are our language for expressing a judgment on sales. It should be emphasized that a single point judgment should not be used--say 850 sales, with a decision based on this figure. A forecast is based on alternatives--with different likelihoods, hence, the judgment of odds. Treat the judgment on the odds like a lottery. For example, you hold 70% of the tickets so you know there are 30% against you. Similarly, you know that if there are ten tickets, you hold 1 through 7; if it is 8, 9, or 10, you lose. If you hold 8, 9, or 10, 70% or 1-7 are against you. Try and find the best judgment on your odds. Use all data available such as records showing sales of similar products, look at market prospects, look for different or peculiar features of the proposed new product that may modify your judgment of the odds. It must be remembered that the monetary aspect must not be a factor in developing your forecast or odds.

In dealing with the risk aspect, which is the final aspect prior to putting the problem together, the writer will attempt to simplify the problem. There are many methods for establishing risks and in the real world this would be handled either by use of utility theories or judgments. For the purpose of this model, assume the amounts of money involved are not significant to our firm. With this premise established, the writer will assume away the risk aspect with a judgment. Having dealt with the three dimensions of the problems, we will now put the problem back together.

The criterion will be the greatest expected monetary value (EMV) of alternatives "A" and "B." The index for the actions covered might be the average weighed by the likelihood (odds) that it will occur demand wise. For example, the EMV of "A" would be:

1/2 of	-$500	(-$250)	Plus	= EMV (+$917)
1/3 of	+$1500	(+$500)	Plus	
1/6 of	+$4000	(+$667)		

The EMV of "B" would be:

1/2 of -$4000 (-$2000) Plus
1/3 of 0 (0) Plus = EMV (-$1167)
1/6 of +$5000 (+ $833)

PAY OFF TABLE AND EMV

Sales Volume	Don't Produce	"A"	"B"	Forecast Odds	EMV A	EMV B
10,000	0	+4000	+5000	1/6	$667	$833
5,000	0	+1500	0	1/3	500	0
1,000	0	-500	-4000	1/2	-250	-2000
					+917	-1167

FIGURE 6

In this case we would choose alternative "A." The EMV of +$917 is an index of the desirability. The larger the number, the more desirable. Thus, the rational decision-maker could look at his model and its results and say monetarily, demand and risk wise, alternative "A" looks more favorable. A side effect is the establishment of the value of perfect information. The monetary value will be the same as the EMV of X (if each amount used was perfect, verifible data).

EMV $0 + $500 + $833 = $1333
minus 917 EMV of "A"
$ 416 Value of perfect information

The significance of the last point is that the more you think you know, the less you will pay for information. If the monetary consequence were ten times, you would pay ten times more for information.

Conclusion

In this chapter, two of the many types of analyses have been demonstrated. The selection was intended to show one method used primarily by the Defense Department and one found popular in the industrial community. The value of using these and similar methods of analyses in decision-making can be stated best by the remarks of A. C. Enthoven:

> We must make defense planning and the selection of weapons systems on an intellectual rather than on emotional process. To do this we must turn our attention to the question of what's right, not who's right.[16]

CHAPTER IV

APPLICATION AND PROBLEMS ASSOCIATED WITH SYSTEMS ANALYSIS

In previous chapters an examination has been made of the need, structure, and methodology of systems analysis. An understanding of this need and the workings of system analysis is necessary in discussing how decision-makers can select from among these systems of choice. The purpose of this chapter is to analyze some applications of systems analysis and illustrate some of the limitations and problems associated with its use. A fundamental background of the subject should provide the decision-maker with a more objective view of the value, limitations, and problems associated with systematic analysis. This fundamental background is also of value to the decision-maker in choosing a method of analysis, the subject of the next chapter.

TFX System

To describe actual application of system analysis the writer will use as a model the analysis process used in the selection of the TFX System. The decision by

Secretary of Defense McNamara to choose General Dynamics/Grumann as the source for the controversial TFX system saw use of some analysis principles such as cost-effectiveness, use of criterion (structural design, commonality for bi-service use), and comparison of data. If we look at the discussion in Chapter II dealing with the various activities in analysis, it becomes apparent that Secretary McNamara went through four of the five major stages--that of formulation, search, explanation, and interpretation. Some might feel that the fifth stage, that of verification, had been dealt with to some degree.[1] The writer would propound that most of the verification prior to award of the contract appears to have been based on prior experience and contractor conducted tests, and thus not entirely complete. By taking each stage separately and looking at the basic steps taken by the Secretary of Defense, we can gain a better understanding of his approach to the problem.

The first stage, that of formulation, was initiated with the decision that the proposed TFX coincided with Secretary McNamara's idea of a weapon system which was required to operate under the "controlled response theory;" i.e., one that provided options on utilization choices such as all-out nuclear strategic capability or tactical use of atomic weapons.[2] This decision led to a second, that a single type aircraft was needed to fulfill the requirements of both the Air Force and the Navy. With this commonality in view, an assumption was made from a cost standpoint . . . that a common TFX would save about one billion dollars and at the same time be versatile enough to meet both Air Force and Navy needs.[3] This belief was consistent with earlier guidance "to procure and operate the force at the lowest possible cost."[4]

The assumption that the TFX was a suitable system, meeting both the needs of the military and the cost constraint built an argument toward agreement in favor of the Secretary's objective—to build a force of TFX's. Having defined the objective, the next stage of analysis, that of search, was entered upon.

In the search stage, the immediate problem of who would produce the system was brought into focus. Using the established procedure of establishing a source selection board, the Air Force, assisted by Navy representatives, requested proposals from ten contractors. The selection board then developed an evaluation criteria, and an evaluation group was selected who set upon the task of evaluating the proposals submitted by the contractors.[5] The data required and the time suspense established presented a very difficult task for the competing contractors. The short time suspense lent some doubt on the validity of the ultimate proposals and supported a belief by some that some companies bid low in order to "buy into" the system and maneuver additional funds as the system progressed.[6] The evaluation group, after review of the proposals, refused to recommend a contractor and proposed that Boeing and General Dynamics/Grumann be awarded study contracts. They felt this would stimulate incentive for competition from both the cost and design standpoint.

This proposal was overruled by the Source Selection Board who recommended that Boeing be given exclusive prime attention. This proposal was felt unsatisfactory and reversed by the Air Force Council and the Secretaries in favor of competition between the two corporations, Boeing and General Dynamics/Grumann. Having accomplished this milestone, the next stage, that of explanation, unfolded.

The explanation stage was set for 12 weeks, but lasted some ten months. The details are not important for the purpose of this study. The significance of the time period is the degree of "over-determination" that occurred in testing the two proposals. Many uncertainties appeared which is normal when dealing with a new system like the TFX. It also appeared to some that the competing companies attempted to exploit the stated requirements of the Secretary of Defense, that of cost and comparison, while not meeting the full question of the Defense objective; to say this feeling in a few words, Richard Elliott states: "the TFX, 'Best Phone Ever Built,' may not be good enough."[8]

Secretary McNamara entered the final phase of his analysis effort, the interpretation stage. He carefully evaluated the data presented him and made a recommendation in favor of General Dynamics/Grumann. He stated that "the General Dynamics program offered a greater opportunity for achieving a high degree of dependability, and at the lowest possible cost."[9] A vital point in this interpretation phase was that Secretary McNamara made his decision apparently in basic disagreement with his chief military advisors. This fact leads to the next phase of analyzing this decision. Is there evidence now that Secretary McNamara made a poor decision or that systematic analysis failed?

Shortcomings in TFX Analysis

When treating the subject of system analysis, it becomes apparent that the ultimate choice by the decision-maker should be objective and not subjective. Total alignment to one objective may lead to what R. N. McKean refers to as an "overdetermined" test. Mr. McKean states it this way: "It is like maximizing the amount of aspirin you buy while simultaneously minimizing the amount of money spent for them."[10]

Secretary McNamara, while pursuing the problem of the "best" TFX source, possibly violated a primary characteristic of fruitful systems analysis, that of using all resources available to him. The writer is inferring that some resources in the field of analysis were available, but apparently not utilized fully; i.e., Alain Enthoven and his group of analysts.[11] Also, a study by Rand might have been of great benefit. If this aircraft system had been subjected to a rigorous analysis discipline such as gaming, with technically experienced military players, it appears possible that the problems now seen would have become apparent and documented before the final decision was made. Problems such as being experienced by the Navy in the area of size and weight would have been obvious if the analysis had considered the possibility of changing technology and the need for modifications which are cited as the cause of the weight problem. The fundamental belief that systems, particularly aircraft, grow, though known did not receive the attention required of a complete and systematic search. Rear Admiral W. I.

Martin states it this way:

> We are greatly concerned about the weight (of the F-111B). It influences nearly all of the performance figures. . . . in one way or another. Weight growth at this point can be a very serious thing, because aircraft are known to grow even after the initial production.[12]

The experiences of the past, in developing aircraft systems, were clearly understood, but these experienced were not fully exploited.

The problem of sensitivity in testing against a model is very important in that certain variables exert a far more significant effect on the solution than do others.[13] In further examining the analysis effort expended on the TFX, the question arises as to whether or not this area of sensitivity was given as high a priority as cost was. In order to react to new requirements of technology, the design weight of the aircraft will have to go up--the only way to decrease the weight is the use of titanium, a very costly metal. While this is a problem for the contractor and not the buyer from the standpoint of profit, it is important because if the problem is not corrected, the major basis for choosing this system--that of cost-effectiveness--will as Mr. McNamara once said, "simply evaporate."[15] The TFX analysis as McNamara saw it was a situation where judgments were pyramided upon judgments.[16] The question of whether Mr. McNamara violated a cardinal premise of good analysis, that of elimination of bias through over determination, may never be known. But what is now known is that he did not fully use all the resources available to him in making his choice.

The use of Mr. Enthoven and his staff of analysts in conducting a complete systematic analysis would surely have identified the problem of what would happen to this system when and if it has to be modified this way or that. They would have also looked carefully at the question of whether the system would be able to meet the original objectives. Such an examination might have concluded that it's all right for the Air Force but now the Navy can't use it. At this point, it might have been determined that two of the basic objectives could not have been met--that of commonality and cost. This discussion is not intended as a criticism of Secretary McNamara but rather it is intended to demonstrate the necessity for completeness when engaged in analysis effort.

Other Problems of Systems Analysis

In describing systems analysis in earlier chapters it was said this type of discipline dealt with the broad problems of higher magnitude. It is for this reason that the problems and pitfalls associated with systems analysis must be carefully avoided.[17] One of the most severe problems faced by a decision-maker is finding the correct type and amount of analysis. The need for an interdisciplinary approach may find the problem of such nature to be outside the available resource of the decision-maker. That is, it may require expertise, time, or funds which the decision-maker does not possess in sufficient quantity. This problem will be discussed more fully in Chapter V.

Many times the objective is incorrectly determined. As with TFX System application example, if more time had been spent in determining the objective in relation to the future and possibly less intuitive judgment on the current need, the ultimate judgment might have been different. A good example of complete systems analysis with clear objectives might be the decision on the Sky Bolt system. This was a lengthy, intuitive, yet systematic, quantitative study of current and future needs. All resources available were placed into motion in this analysis effort. It appears to have been a classic example of successful system analysis.

An analysis based on limited objectives may produce a logical alternative or choice but ignore other more valid alternatives due to the limited objective. An example would be the cost-effectiveness studies conducted in comparing modern aircraft carriers with other weapon systems.[18] "In comparing alternatives for limited war roles, these studies took no account of the carriers' general war capability in a comparison with weapons systems that had almost no capability in other roles."[19]

Faulty data is an extremely sensitive problem that is always possible with analysis of any kind. There are several kinds of faulty data; one is what Dr. Quade refers to as blind acceptance of "official figures."[20] "Official" figures can be very damaging to an analysis effort due to the spectrum they can run. What is given as "official" may be very bias, very parochial, or very subjective. It has been said that you can prove anything with statistics. The same case may be made for improper system analysis using faulty data. An associated problem with "official" data is that the analyst may actually believe his data to be correct and complete while this may not be true. Much of the decision-maker's confidence toward analysts and their product lies in the standard the analysts set in gathering data. Kahn states that "he must do enough cross-checking to convince himself that, in all probability, he has the correct facts, and then he takes his chances."[21] To over cross-check, however, is wasteful and does not improve the validity or credibility of the end product.

Many times the limitations of time and money result in the problem of <u>incompleteness</u> in analysis.

> Typically, other costs have the same effect. For instance, we would like to find out what the Soviets would do if we put an armed Minuteman on Moscow. One way to get this information would be to launch a Minuteman. But while this might be cheap in dollars, the likelihood of other costs precludes at once this type of investigation.[22]

This problem of incompleteness involves the possibility of large uncertainties, especially in the area of military effectiveness or future strategy or technology.

Finally, there is the common tendency to have competing analysis activities confront the decision-maker with alternative choices which may have been created to influence the decision-maker's choice. If a design, model, or strategy is known to be preferred, the decision-maker must make not only judgments on the final decision but as Mr. McNamara states, "also on the underlying recommendations and facts."[23] Confidence in the objectivity of the analyst by the decision-maker is necessary. This is especially true when the analyst is known to have made decisions and judgments based on his best rationale and intuitive reasoning.

CHAPTER V

HOW A DECISION-MAKER CHOOSES A METHOD OF ANALYSIS

The problem of how a decision-maker selects the proper method of analysis is actually a two-part question. The question of which method of analysis to use is dependent on many factors, including the basic second question of how much of his resources he should expend. Many who advocate the use of systematic analysis in decision-making find extreme difficulty in establishing firm guidelines for the decision-makers to use in making these preliminary decisions. With the absence of any guidelines, it therefore becomes obvious that a preliminary investigation, or in a sense an analysis, by the decision-maker, must take place. He must examine his purpose for conducting the analysis effort, the complexity of the problem, and the degree of uncertainties that exist. Additionally, he must examine his resources of time, money, and people in order to weigh their relative cost against effectiveness of results expected. Consequently, before embarking on any analysis effort, a critical diagnosis is necessary.

> Accurate diagnosis is the essential first phase of sound decision-making. Unless the initial diagnosis is correct, all subsequent planning will be futile.[1]

This is the key to success in making correct choices--choosing both the method and the expenditure of resources.

The advent of modern systems analysis is much like the early period of data automation. The idea that the use of a computer was a necessity to all progressive companies was, of course, false. But the early period of computers found companies obtaining equipment that was not compatible to their operation nor advantageous from the viewpoint of economy. Many would-be users obtained equipment prior to deciding what they wanted it to do for them or if it was worth the expenditure of money and people. This situation is much like analysis efforts. Analysis for analysis sake is not reasonable or economical. Many problems faced by decision-makers do not lend themselves to substantial systematic or quantitative analysis efforts from either the standpoint of depth or relative importance.

One of the major problems in the initial diagnosis is the attitude of the decision-maker toward the problem. "Organizations do consist of human beings, regardless of how many machines are employed, and hence must be considered as phenomena of human behavior."[2] This idea of human behavior is the stem of the problem in a decision-maker's attitude. If a manager is traditionally autocratic in pronouncing judgment on problems, then his initial diagnosis will reflect his personal judgment and has only a questionable chance of being correct in the majority of situations. It is this human aspect that provides one of the first guidelines needed in arriving at choices in methods of analysis and the expenditure of resources. The writer will call it <u>credibility of the individual</u>. A simpler term might be experience, but experience alone does not always provide the objectivity necessary in a successful decision-maker.

> The decision-maker or analyst in perceiving a solution may only be deceived by the weight of his own preferences. The important task is not one of reducing the human element but of clearly identifying it and integrating it into the concrete elements of analysis.[3]

Thus it becomes obvious that while the leadership role of the decision-maker is very important, it must be made credible by being consistently objective in decisions. In choosing the term credibility in preference to the term experience, it should be understood that only through experience can valuable, correct, and intuitive judgments be made. The first premise is therefore established. A credible decision-maker must possess experience, objectivity, and an ability to make decisions based on sound intuitive judgments.

> The ingredient of human judgment be it only the simplest kind of intuition is therefore an essential part of any study of policy, no matter how analytical such a study might be. Judgment can be aided and guided by the techniques of scientific analysis, but it can never be supplanted.[4]

Having established the requirements needed by a decision-maker and the need for preliminary diagnosis, the next step that is necessary in making the initial choices of method and expenditure of resources in the analysis effort is the sequential process.

In the sequential process there are basically two decisions.

> A terminal decision--This is a selection of the course of action, the decision, which will terminate the sequential decision process.
> A continuation decision--This is a decision between continuing to obtain information, with attendant time delay and cost, and making a terminal decision.[5]

The problems which attend most significant problems such as time pressures, cost, utility, and diminishing return begin to bear on the problem. At some point, time pressures may dictate a terminal decision. Time pressures may be a prime consideration from the standpoint of choice. If a decision-maker is faced with a dynamic decision, he must react within time constraints with the most rational and intuitive judgments possible.

Systems analysis efforts are very sensitive to time constraints. The magnitude of the seriousness of these constraints are directly proportional to the scope of the problem and the dynamic nature of the situation. The time range can be extremely wide, from immediate to the distant future. The Department of Defense, in dealing with this problem, has been forced to react from both ends of the spectrum. James R. Schlesinger states: "Some of the major choices of Secretary McNamara were made when only the scantiest cost data were available and when our understanding of our strategic objectives and Soviet capabilities remained obscure . . ."[6] This clearly describes choice as a result of time pressure. The other extreme could be described by the lengthy analysis conducted on the Air Force B-70 system by Secretary McNamara. The decisions in this case were based primarily on complete analysis with much less regard for time pressures or cost but more regard on eventual utility.

Resource of People

The resource of people may provide a basis for a decision-maker's choice as to what type of analysis he might undertake. It is logical to believe that in a major problem, like national security, the decision maker will be inclined to focus whatever resources he may possess in successfully finding correct alternatives. On the other hand, he could find that he has multiple problems of equal priority which require analysis. He must make tradeoffs between these problems. For example, he may find that his resource of people are engaged in an analysis of a problem of such depth and time pressures that they may be denied to him. The decision-maker must then turn to an alternate source for assistance or accept a compromise tradeoff solution of delaying analysis of another problem, or accepting a lesser analysis of both problems. For example, we will assume the Secretary of Defense has given his analytical staff a problem on the nature of the missile gap. Time and national security dictate immediate results. At the same time an analysis of a problem on the feasibility of using space craft as a war-making system is required by the President. The Secretary must decide whether he should constrain the missile gap study by assigning his staff the additional and unassociated requirement to analyze the feasibility of the space craft as a war-making system, or whether he should turn to a non-profit firm such as Rand Corporation or MITER for the analysis. In making his diagnosis he may determine that the professional experience is not present on his staff and again turn to the non-profit group for the analysis.

Cost As a Constraint

The problem of cost will often determine both the type and amount of analysis to be conducted. The best way to describe the use of cost as a method of determining the effort to be expended is the "pay-off." The cost can take many forms. Cost in money, people, and time are equally important, but the decision-maker needs some basis for his expenditure. A "pay-off" in terms of deterrence and national security may or may not be tangible in the form of money savings. There are some problems that may face a decision-maker where cost is not felt to be of any significant importance. An example might be an analysis conducted on a system that could eliminate war or business failures forever. Even in this sense there is a "pay-off" both from the intangible sense as well as the tangible sense. A successful analysis could mean a reduction in the intangible threat of war and the tangible cost of defense. The presence of a positive or negative "pay-off" will dictate the decision-maker's choice in all cases.

The Ultimate Basis of Choice

The "pay-off" to the decision-maker will always lead him to his ultimate choice of method and amount of resource expenditure. Is it always possible to know precisely what the ultimate "pay-off" will be? The answer is no. However, a basis for using systems analysis is that uncertainties and unverifiable data can be treated successfully. Therefore if reasonable values for services can be established, a useful "pay-off" table can be constructed. The age old question of "how much is enough?" can be answered by modern methods. A choice of what is enough may be ultimately proven wrong, but if the investigation is systematic and has reasonable values attached, the probabilities of success are increased.

There is a trend to say that the "pay-off" may be settled in the cost-effectiveness ratio. This can be very misleading in that unless absolute levels of effectiveness are specified, the preferred alternatives cannot be determined. This can be a very dangerous criterion on which to base expenditure of resources. The cost or the effectiveness may not cover the problem completely; thus, the payoff is inaccurate or inconclusive alternatives.

The real "pay-off" is where the decision-maker has a choice between a wide range of alternatives at various costs to him, or he may examine a range of sub-systems again at varying costs. This writer believes that the ultimate way in which a decision-maker can arrive at a fruitful decision is to apply some systematic methodology to his decision in choosing which type of analysis he should use and how much of his resources he should expend.

Application of Pay Off Table*

In Chapter III, a method of analysis called "Pay Off Table" was described as a useful decision-making tool. This table when constructed provides a decision-maker with useful information from three considerations:

1. The monetary aspect--an analysis of the expense involved and the expected return in revenue or services.

2. The aspect of forecasting--the uncertainty or the demand.

3. The risk--how much can be gained or lost. This section of the thesis will show an application of a pay off table to the problem of selecting an analysis method and determining how much resources the decision-maker should expend on varying levels of analysis effort. Additionally, the model will provide the return in numbers of alternatives or subsystem analysis he will get and still have a profitable analysis effort.

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*The thoughts on pay off table were obtained from a lecture by Dr. Paul A. Vatter, "Decision Making,"[53] to students of Air Command and Staff College 14 September 64.

Some assumptions must be made in order to apply this type problem to the pay off table.

1. The writer will present an over-simplified problem and model.

2. The points are over-simplified for ease in understanding by the reader and does not constitute a weakness in the method.

3. The values assigned for services are arbitrary and are also intended only to provide data for the construction of the pay off table.

The reader must assume the role of a high level decision-maker, who has a mulit-million dollar system under consideration. The system is unique in that there are many uncertainties and very little experience or data in the area, thus an analysis of the system is desired. Being a large and complex system, the decision-maker wants to know whether or not it will be profitable to use one type of analysis over another and to what degree he should expend his resources.

He wants to know how many valid alternatives he will get for a given expenditure; also, he wants to know how many subsystems can be analyzed for a price. In any event he wants to see what the "pay off" of his various analysis alternatives will be. In order to proceed with the models, it must also be assumed that there is a value to the decision-maker in having valid alternatives and analysis of subsystems.

The decision-maker has three alternatives:

A. Don't do any analysis.

B. (1) Apply ten analysts for six months.

(2) Cost will be $100,000.

C. (1) Apply 20 analysts for six months.

(2) Cost will be $175,000.

(Costs include salaries and analysis expenses.)

For the purpose of this model, assume the value of each valid alternative uncovered to be $10,000 and each subsystem analyzed to be $10,000. The model (Figure 7) is an over-simplified example of the technique used in this type analysis. The first column on the left, for example, shows only three ranges of alternatives. This range could vary from zero to points in between those given or above the highest shown. The analysis alternatives have been limited to three; again, others could have been considered.

In breaking down this problem and solving each part separately, the monetary will be covered first. Entering the table (Figure 7), the first alternative of not doing any analysis, all zeroes would be placed by all new systems alternatives, as nothing was gained or lost. Looking at alternative "B" with a fixed cost of $100,000,

PAY OFF TABLE

		ALTERNATIVES		
		"A" Don't Do Any	"B" Method	"C" Method
New System Alternatives	20	0	+$100,000	+$25,000
	15	0	+ 50,000	- 25,000
	5	0	- 50,000	-125,000

FIGURE 7

it is determined that five new systems alternatives would result in a loss of $50,000 ($100,000 cost minus $50,000 value of new alternatives). Using the same cost data with 15 new alternatives, a profit of $50,000 is made ($150,000 value of new alternatives minus $100,000 cost of analysis). And finally, again using the same cost data, a profit of $100,000 is made ($200,000 value of new alternatives minus $100,000 cost of analysis).

Moving to the last analysis, alternative "C" with a fixed cost of $175,000, we again enter the table with five new systems alternatives. This would result in a loss of $125,000 ($175,000 cost minus $50,000 value of new alternative). With 15 new system alternative, a loss of $25,000 occurs ($175,000 cost minus $150,000 value of new system alternative) and at 20 new system alternative, a profit of $25,000 ($200,000 value of new alternative minus $175,000 cost). The aspect of the monetary consideration has thus been handled without complicating the next consideration--that of "forecasting."

We are now dealing with uncertainty, the question of what we really think the odds are. Using the model (Figure 7) 5, 15, or 20 new valid systems alternatives will result from an analysis effort. It is here that work with the betting odds begins. We will say that the odds are one in two that we get five valid alternatives; one in three that we will get 15 valid alternatives; and one in six that 20 valid alternatives are produced. A forecast is based on alternatives--with different likelihoods, hence the judgment of odds. Try and find the most valid odds. Use all data available such as records of past experience; look for different or peculiar features that may affect your judgment of the odds. Do not let the monetary aspect be a factor in developing your forecast or odds.

In dealing with the final aspect, that of risk, the writer will again simplify the problem. While there are many methods for establishing risk--by utility theories or judgment, they will not be considered necessary for this problem. Assume the amounts of money involved are not unusual to the decision-maker cost wise, but the pay off may be significant in terms of alternatives with far-reaching values. Therefore, the writer will assume away the risk with a judgment.

We will now put the problem back together. The criterion for the solution of the problem will be the greatest "Expected Monetary Value" (EMV of Alternatives "B" and "C").

PAY OFF TABLE AND EMV

New System Alternatives	ALTERNATIVES					
	"A" Don't Do Any	"B"	"C"	Forecast Odds	EMV Data "B"	"C"
20	0	+$100,000	+25,000	1/6	+16,666	+4,166
15	0	+ 50,000	-25,000	1/3	+16,666	-8,333
5	0	- 50,000	-125,000	1/2	-25,000	-62,500

FIGURE 8

The index for the actions covered might be the average weighed by the likelihood (odds) that it will occur. For example, the EMV of "B" would be:

1/2 of -$50,000 (-$25,000) Plus
1/3 of +$50,000 (+$16,666) Plus = EMV ($8,332)
1/6 of +$100,000 (+$16,666)

The EMV of "C" would be:

1/2 of -$125,000 (-$62,500) Plus
1/3 of -$25,000 (-$8,333) Plus = EMV (-$66,667)
1/6 of +$25,000 (+$4,166)

In this case we would choose alternative "B." The EMV of +$8,332 is an index of the desirability. The larger the number, the more desirable. Thus, the decision-maker could look at this model and its results say that from a monetary, uncertainty, and risk standpoint, alternative "B" is more favorable.

CHAPTER VI

CONCLUSIONS

An understanding of the factors a decision-maker must consider in selecting the method and extent of analysis effort is necessary in order to perform fruitful analysis efforts. In previous chapters, needs, methodology, application, and problems with analyses have been treated. The question of method and how much to expend in the effort, can be determined if--as with the use of the pay off table in Chapter V--an unbiased, objective, rational, and systematic discipline is used. The writer believes that with careful attention to values, the model, and methodology of the "pay off" type analysis, many difficult decisions as to method and extent of resource application could be satisfactorily reached by decision-makers.

It is also concluded that careful choices in method of analysis and expenditure of resources will result in fruitful analysis efforts. Decision-makers must:

1. Insure that the choice of method and extent of analysis best achieves their objective.

2. Remember that analysis does not solve problems

or always provide the most correct choice, but rather it eliminates poorer and inefficient choices.

3. Carefully select their diagnosis criteria to insure that the method and extent of analysis selected is relative to the objective of the analysis.

4. Be aware that sound judgment and intuitive reasoning in selecting method of analysis and resource application is still a basic requirement when using analysis as a decision-making tool.

Recommendation

Recommend that the Department of Defense provide guidance to decision-makers which will insure that all the factors considered in this thesis are carefully examined before a method of analysis or expenditure of resources is made.

FOOTNOTES

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3. Ibid., p. 2.

4. William H. Newman and Charles E. Summer, The Process of Management (Englewood Cliffs, N. J.: Prentice-Hall), p. 252.

5. Ibid., p. 256.

6. Ibid.

7. Ibid., p. 270.

8. A. C. Enthoven and H. S. Rowen, "An Analysis of Defense Organization," Rand Corporation Report No. P-1640, Santa Monica, California (March 17, 1959), p. 31.

9. Lt Col Pursley, 25 October 1965, to Air Command and Staff College students.

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1. E. S. Quade, (ed.), "Analysis for Military Decision," Rand Corporation Report R-387-PR, Santa Monica, California (November 1964), p. 153.

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3. Quade, Analysis, p. 2.

4. Ibid., p. 4.

5. Ibid., p. 7.

6. *Ibid*.

7. *Ibid*., p. 7.

8. Alain C. Enthoven, "Systems Analysis and Decision-Making," *Military Review*, Vol. XLIII (January 1963), p. 8.

9. Quade, *Analysis*, p. 159.

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11. *Ibid*., p. 307.

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1. C. J. Hitch and R. N. McKean, The Economics of Defense in the Nuclear Age (Cambridge: Harvard University Press, 1961), p. 23.

2. Ibid., p. 166.

3. Ibid.

4. Ibid., p. 23.

5. J. E. Walden, J. E. Reid, J. E. Jakes, H. J. Jacobs, F. M. Pahl, "The Cost-Effectiveness Method," Research Study, 1964 (Maxwell AFB, Alabama: Air University), p. 27.

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9. Ibid., p. 30.

10. Quade, Cost Effectiveness, p. 3091.

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12. Lecture, Topic: The Defense Budget, delivered by Charles J. Hitch to Industrial College of the Armed Forces, 17 October 1961, p. 2.

13. "Decision Making in the Defense Department," Address April 20, 1963, Vital Speeches, June 1963, pp. 508-512.

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Chapter IV

1. Quade, Analysis, p. 158.

2. Thomas G. Darling, "Decision Making in the Department of Defense (Unpublished Thesis #0357-64, Maxwell Air Force Base, Alabama: Air University, April 1964).

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